Fire Effects Information System (FEIS)

FEIS Home Page

SPECIES: Abies grandis

Pole-sized grand fir. Image used with permission of Chris Schnepf, Bugwood.org.

INTRODUCTORY

SPECIES: Abies grandis

AUTHORSHIP AND CITATION:

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Revisions: On 8 December 2017, the Fire Case Study summarizing research by Shearer et al. was updated to a Research Project Summary. Photos were added to this Species Review at that time.

ABBREVIATION:

ABIGRA

SYNONYMS:

No entry

NRCS PLANT CODE [186]:

ABGR

COMMON NAMES:

grand fir
lowland white fir

TAXONOMY:

The scientific name of grand fir is *Abies grandis* (Dougl.) Lindl. (Pinaceae) [104,110,102].

Grand fir hybridizes with white fir (*A. concolor*) [116,45]. A broad zone of intergraded grand × white fir populations occurs from northeastern Washington and Oregon south to northern California and east to west-central Idaho [174].

LIFE FORM:

Tree

FEDERAL LEGAL STATUS:

No special status

OTHER STATUS:

No entry

DISTRIBUTION AND OCCURRENCE

SPECIES: Abies grandis

- GENERAL DISTRIBUTION

GENERAL DISTRIBUTION:

Grand fir has a split distribution. Along the Pacific Coast it occurs from southern British Columbia south to Sonoma County, California, and east to the Cascade Range of central Oregon. In the continental interior it occurs from the Okanagan and Kootenay lakes region of British Columbia south to eastern Oregon, central Idaho, and west of the Continental Divide in Montana [71,174].

Grand fir is planted for lumber and as an ornamental in Hawaii [168] and Europe [141].

ECOSYSTEMS [77]:

FRES20 Douglas-fir
FRES21 Ponderosa pine
FRES22 Western white pine
FRES23 Fir-spruce
FRES24 Hemlock-Sitka spruce
FRES25 Larch
FRES27 Redwood
FRES28 Western hardwoods

STATES:

CA HI ID MT OR WA BC

BLM PHYSIOGRAPHIC REGIONS [21]:

1 Northern Pacific Border
2 Cascade Mountains
3 Southern Pacific Border
5 Columbia Plateau
8 Northern Rocky Mountains

KUCHLER [121] PLANT ASSOCIATIONS:

K001 Spruce-cedar-hemlock forest
K002 Cedar-hemlock-Douglas-fir forest
K003 Silver fir-Douglas-fir forest
K006 Redwood forest
K007 Red fir forest
K008 Lodgepole pine-subalpine forest
K011 Western ponderosa forest
K013 Cedar-hemlock-pine forest
K014 Grand fir-Douglas-fir forest

K015 Western spruce-fir forest
K025 Alder-ash forest
K026 Oregon oakwoods

SAF COVER TYPES [56]:

206 Engelmann spruce-subalpine fir
207 Red fir
210 Interior Douglas-fir
211 White fir
212 Western larch
213 Grand fir
215 Western white pine
218 Lodgepole pine
221 Red alder
222 Black cottonwood-willow
224 Western hemlock
225 Western hemlock-Sitka spruce
226 Coastal true fir-hemlock
227 Western redcedar-western hemlock
228 Western redcedar
229 Pacific Douglas-fir
230 Douglas-fir-western hemlock
231 Port-Orford-cedar
232 Redwood
233 Oregon white oak
237 Interior ponderosa pine

SRM (RANGELAND) COVER TYPES [163]:

109 Ponderosa pine shrubland
110 Ponderosa pine-grassland
409 Tall forb
422 Riparian

HABITAT TYPES AND PLANT COMMUNITIES:

Grand fir is an indicator of productive forest sites [80,88,117]. Mature grand fir stands are usually floristically diverse [43,71]. Common plant community associates of grand fir are grouped below by region.

Western Montana and northern Idaho: In Montana, the grand fir habitat type is often bound by Rocky Mountain Douglas-fir (*Pseudotsuga menziesii* var. *glauca*) habitats on warmer, drier sites and by subalpine fir (*Abies lasiocarpa*) on cooler sites. In northern Idaho, the grand fir type merges into western hemlock (*Tsuga heterophylla*) and western redcedar (*Thuja plicata*) on cooler sites [145]. Western larch (*Larix occidentalis*), Rocky Mountain lodgepole pine (*Pinus contorta* var. *latifolia*), and Pacific ponderosa pine (*P. ponderosa* var. *ponderosa*) are major seral species in climax interior grand fir habitats [49,74,145,172]. Understory associates are many: pachistima (*Pachistima myrsinites*), common snowberry (*Symphoricarpos albus*), Saskatoon serviceberry (*Amelanchier alnifolia*), baldhip rose (*Rosa gymnocarpa*), blue huckleberry (*Vaccinium membranaceum*), white spirea (*Spiraea betufolia*), twinflower (*Linnea borealis*), beargrass (*Xerophyllum tenax*), queencup beadlily (*Clintonia uniflora*), and wild ginger (*Asarum caudatum*) are among the most common [43,145,49].

Washington, Oregon, and California: Grand fir occurs on moist to dry sites in the Cascade Range. Overstory associates on moist sites may include western hemlock, western redcedar, Pacific silver fir (*Abies amabilis*), and Sitka spruce (*Picea sitchensis*)[46]. Mid- and understories are diverse and dense on moist sites and commonly include Pacific yew (*Taxus brevifolia*), red alder (*Alnus rubra*), Pacific dogwood (*Cornus nuttallii*), redstem ceanothus (*Ceanothus sanguineus*), shinyleaf ceanothus (*C. velutinus*), thimbleberry (*Rubus parviflorus*), huckleberries (*Vaccinium* spp.), pachistima, queencup beadlily, and/or vanillaleaf (*Achlys triphylla*). Hot, dry sites are usually open and less diverse, with Pacific ponderosa pine, Rocky Mountain Douglas-fir and western white pine (*Pinus monticola*) as common overstory associates. Understories are typically grassy and dominated by pinegrass (*Calamagrostis rubescens*) and elk sedge (*Carex geyeri*) [33,115,181].

Old-growth grand fir on the Umatilla National Forest, Oregon. Image used with permission of Dave Powell, USDA Forest Service (retired), Bugwood.org.

In the Willamette Valley of Oregon, associates of grand fir in coastal Douglas-fir-Oregon white oak (*Pseudotsuga menziesii* var. *menziesii-Quercus garryana*) include incense-cedar (*Calocedrus decurrens*), Pacific ponderosa pine, California black oak (*Q. kelloggii*), chinquapin (*Chrysolepsis chrysophylla*), Pacific madrone (*Arbutus menziesii*), and bigtooth maple (*Acer macrophyllum*) [42].

In southwestern Oregon and northwestern California, grand fir is common in mixed evergreen and conifer forests [102], where it is associated with Shasta red fir (*Abies magnifica* var. *shastensis*), noble fir (*A. procera*), redwood (*Sequoia sempervirens*), western hemlock, Sitka spruce, and coastal Douglas-fir [2,102]. Mid-story and shrub associates in redwood forest of Redwood National Park, California, include tanoak (*Lithocarpus densiflorus*), Pacific madrone, evergreen huckleberry (*Vaccinium ovatum*), red huckleberry (*V. parvifolium*), and Pursh's buckthorn (*Frangula purshiana*). Commonly associated ferns and herbs include western sword fern (*Polystichum munitum*), deer fern (*Blechnum spicant*), Oregon oxalis (*Oxalis oregana*), and salal (*Gaultheria shallon*) [125].

Hall [91] arranged grand fir plant associations by fire regime and grand fir's successional position in the plant community. Detailed lists of understory plants are included in habitat type and community type manuals for each region. Vegetation classifications describing plant communities in which grand fir is a dominant species are listed below.

Forest habitat types of northern Idaho: a second approximation [43]
Forest vegetation of eastern Washington and northern Idaho [49]
Classification of grand fir mosaic habitats [61]
Forest vegetation of the montane and subalpine zones, Olympic Mountains, Washington [72]
Natural vegetation of Oregon and Washington [74]
Plant communities of the Blue Mountains in eastern Oregon and southeastern Washington [88]
Classification and management of Montana's riparian and wetland sites [96]
Plant association and management guide: Willamette National Forest [101]
Riparian reference areas in Idaho: a catalog of plant associations and conservation sites [106]
Forest habitat types of Montana [145]
Major Douglas-fir habitat types of central Idaho: a summary of succession and management [173]
Plant association and management guide for the grand fir zone, Gifford Pinchot National Forest [181]
Forest plant associations of the Colville National Forest [193]
The redwood forest and associated north coast forests [197]

MANAGEMENT CONSIDERATIONS

SPECIES: Abies grandis

WOOD PRODUCTS VALUE:

Grand fir is a commercially valuable timber species. The wood is compatible with adhesives, has low shrinkage, and is good for pulping and other light-duty uses [14,21,71,167]. It is lighter in weight and not as strong as the wood of most pines. The best commercial stands grow in the Nez Perce and Clearwater national forests of northern Idaho [71].

IMPORTANCE TO LIVESTOCK AND WILDLIFE:

Browsing: Livestock seldom browse grand fir but do use it for shade [10x]. Deer, elk, and moose may resort to eating fir (*Abies* spp.) needles in winter [127]. Fir needles are a major part of the diet of blue, ruffed, and sharp-tailed grouse. Squirrels, other rodents, and some birds such as nuthatches and chickadees eat the seeds [127,179].

Habitat use: Mature grand fir provide nesting and feeding sites for a variety of arboreal animals [14]. Several species of owl including the flammulated [32] and northern spotted owl use grand fir habitats [36]. Marbled murrelet nest in old-growth grand fir-coastal Douglas-fir habitat in northern California [142]. Woodpeckers use grand fir habitats but often select other tree species within the type over grand fir for foraging and nesting [14,26,29,118,129]. In a study of woodpecker foraging activities in the Blue

Mountains of Oregon, Bull and others [30] found that foraging among 8 species of woodpecker was consistently lower on grand fir than on Pacific ponderosa pine, Rocky Mountain lodgepole pine, western larch, and Rocky Mountain Douglas-fir.

Most big game species do not prefer mature grand fir forests, but they use seral-stage grand fir habitats. Irwin and Peek [105] found that elk in northern Idaho preferred early-seral, grass and shrub/grass stages of grand fir habitats, especially when foraging in spring. When seeking shade and resting cover, elk tended to use adjacent western hemlock and lodgepole pine over grand fir forest. In the Selway-Bitterroot Wilderness of northern Idaho, mule deer avoided mature grand fir/queencup beadlily habitat but used 3-year-old burns in grand fir/queencup beadlily in proportion to availability. White-tailed deer tended to avoid both mature and old-seral grand fir/queencup beadlily habitats [113].

Unlike most big game, moose prefer old-growth grand fir forest. Pierce and Peek [146] found that grand fir/Pacific yew was critical winter habitat for Shiras moose in north-central Idaho, with Pacific yew being their primary winter food item.

PALATABILITY:

Firs (*Abies* spp.) are generally unpalatable to big game animals. Deer, especially white-tailed deer, browse grand fir in winter when more palatable forage is unavailable [127].

NUTRITIONAL VALUE:

Grand fir foliage (oven-dry weight) contains approximately 1.4% nitrogen, 0.20% phosphorus, and 0.7% potassium [55].

COVER VALUE:

Grand fir provides good thermal and hiding cover, often close to water, for big game animals [108]. Young trees provide good cover for grouse and small mammals including squirrels, chipmunks, and pikas [127]. Grand fir's thick boughs provide shelter during rainstorms and provide roosting sites for grouse, pileated woodpecker, Williamson's sapsucker, pygmy nuthatch, Vaux's swift, and red crossbill [14,127,27,30]. Lists of bird and mammals that use grand fir in the Blue Mountains are available [180].

Old-growth live grand fir and grand fir snags provide nesting sites for woodpeckers, sapsuckers, deer mouse, bushy-tailed woodrat, American marten, fisher, spotted skunk, squirrels, and weasels [14,180,182]. Rats, mice, squirrels, weasels, and bears use downed grand fir logs and hollowed trunks as dens [14]. Pileated woodpecker and flammulated owl in the Blue Mountains of Oregon and Washington select large-diameter live grand fir, especially trees with broken tops that are extensively decayed by Indian paint fungus (*Echinodontium tinctorium*), for nesting [2,180,26,31,32]. Most grand fir may not attain a large enough girth to be preferred pileated woodpecker nesting sites, however. On the Coram Experimental Forest of northwestern Montana, pileated woodpecker preferred nesting in large-diameter, fungi-decayed western larch, Pacific ponderosa pine, western white pine, and black cottonwood (*Populus trichocarpa*) over grand fir, which was less common and generally smaller in dbh than the preferred nest tree species [129].

VALUE FOR REHABILITATION OF DISTURBED SITES:

Since grand fir grows well in a variety of environments including riparian areas, it is a good candidate for planting on disturbed sites [91,95].

OTHER USES AND VALUES:

Grand fir is grown commercially for Christmas trees [71,175]. It is also planted as an ornamental [71,120].

The Salish of Vancouver Island, British Columbia, collected pitch from grand fir blisters, rubbed it into wooden implements, and scorched it to provide a varnished finish [184]. They made a decoction from the branches and cones to treat respiratory ailments; a poultice from the pitch to treat wounds, burns, and sore eyes; and a decoction of the bark, sap, and sapwood to treat gonorrhea [185].

□THER MANAGEMENT CONSIDERATIONS:

Pests and diseases: Grand fir is susceptible to a variety of pathogens [16,22,71,189,139,174]. Fire exclusion and selective harvesting of pine and western larch that began at the turn of the century have resulted in an unprecedented abundance of grand fir in many areas of the interior West. Disease and mortality are greater in fir-dominated stands than in stands dominated by seral conifers. As a result, these late-successional stands are dominated by diseased, suppressed, and/or dead grand fir [63,139].

Grand fir is susceptible to heart- and root-decaying fungi because it does not exude heavy pitch over wounds or contain decay-inhibiting properties in its wood. Annosus (*Fomes annosus*), armillaria (*Armillaria ostoyae)*, and Indian paint fungus (*Echinodontium tinctorum*) are among the most ubiquitous. Annosus gains entry through fire scars, dead branches, frost cracks, and mechanical injuries [7,8,16,71,62]. Armillaria infects roots by vegetative spread of mycelium across roots. Indian paint fungus infects small branchlet stubs. Fire injury to host trees may stimulate dormant Indian paint fungus to resume growth, accelerating decay [62].

Grand fir is susceptible to numerous insects. The most troublesome are western spruce budworm, Douglas-fir tussock moth, western balsam bark beetle, and fir engraver beetle [71,80,117]. Timing of, and slash disposal following, thinning are important precautions in avoiding fir engraver attacks [189]. Several genera of moths, beetles, and flies eat the cones and seeds [65,71]. A list of insecticides suitable for grand fir is available [93].

Grand fir is the principal host of white fir dwarf-mistletoe (*Arceuthobium abietinum* f. sp. *concoloris*) in the Coast Ranges of Oregon and northern California and the Blue Mountains. Hemlock dwarf-mistletoe (*A. tsugense*) infects grand fir occasionally [86,99,100].

Silviculture: Grand fir can contribute considerable volume to forest stands [117,182], but its strong tendency to develop heart rot makes it less desirable as a leave tree than pines and western larch [9]. Hall [90] compared and summarized several studies of grand fir productivity. Grand fir grows rapidly on cutover or burned sites under favorable conditions [113]. Seedlings on Vancouver Island have grown as much as 3 feet (0.9 m) per year [14]. Grand fir may respond to release, but growth depends on prerelease vigor, site, and logging damage [60,80,117]. Older, low-vigor trees continue to grow at a very slow rate while young, vigorous trees show rapid growth [60,117,159]. Stocking level recommendations for grand fir are available [40,159].

Recommendations for managing grand fir have been summarized for the eastern Cascades of Washington [22], the Blue Mountains [150], and northern Idaho [189].

Harvesting for restoration: Restoring ponderosa pine, western larch, and other fire-dependent communities without the use of prescribed fire is difficult but possible. Mutch and others [139] recommend a series of stand entries, using selective harvesting of grand fir and other shade-tolerant species and mechanical treatment of fuels, where prescribed burning cannot be achieved. They caution, however, that soil productivity and general forest health are usually reduced, and exotic weed cover increased, under treatments other than prescribed fire.

Herbicides: Grand fir is rated intermediate in sensitivity to glyphosate [22].

BOTANICAL AND ECOLOGICAL CHARACTERISTICS

SPECIES: Abies grandis

GENERAL BOTANICAL CHARACTERISTICS:

Grand fir is a native tree. It characteristically has a wide crown, although there is considerable variation in crown width and continuity [14,57]. Heights of mature trees range from 140 to 200 feet (43-61 m) along the coast and from 131 to 164 feet (40-50 m) inland [71,104]. The bole of mature trees may reach 79 inches dbh (200 cm) on the Washington coast but usually ranges from 20 to 40 inches dbh (51-102 cm) [71]. Bark is thin on young trees (mean=0.9 cm for a 20-cm diameter tree) and moderately thick at maturity (m=1.7 cm for a 40-cm diameter tree) [14,144,169]. Finch [64] projected that the bark of a grand fir is 4.3% of the tree's dbh. (For comparison, western white pine and western larch are 1.8 and 7.4% of tree dbh, respectively).

Grand fir has a well-developed taproot [14,103,124,134]. On dry sites the taproot grows to moderate depths while on moist sites shallow lateral roots prevail, and the taproot may be absent [71]. Depth of horizontal roots is moderate compared to associated conifers [103,124,134].

Several morphological characteristics of grand fir lend to its relative flammability. Branching habit is low and dense; stands tend to be dense as well [169]. The foliage has a higher surface-to-volume ratio than that of associated conifers, and the needles are retained longer on the tree (m=7 years) [112]. On the Priest River Experimental Forest in northern Idaho, foliage comprised a greater proportion of total crown weight in grand fir than in 8 associated conifer species. Biomass allocation to smaller-diameter branchwood (< 2 inches (5 cm)) relative to larger-diameter branchwood was also greater in grand fir than most associated conifers [57].

Older grand fir support pervasive rotting fungi but frequently reach 250 years of age and occasionally exceed 300 years [14,71]. Camp [34] found that in the Cascade Range of Washington, grand fir in 21 late-successional stands ranged from 15 to 256 years of age, with a mean age of 83 years.

Grand fir is moderately drought tolerant [34].

RAUNKIAER [147] LIFE FORM:

Phanerophyte

REGENERATION PROCESSES:

Grand fir cones. Image used with permission of Dave Powell, USDA Forest Service (retired), Bugwood.org.

Cones: Cone and seed production begins at 20 to 50 years of age, and cone productivity increases with age [54,174,183]. In a good year, an average grand fir tree produces over 40 cones [71]. A year of heavy cone production is typically followed by several years of light production [73,158,174,185,179]. Pollen and ovulate cones begin development during the summer and go through a period of winter dormancy before pollination, fertilization, and seed production the 2nd spring and summer [165]. Hard frosts may inhibit cone development [71].

Seeds: Trees in Oregon and Washington may produce over 200 seeds per cone [74]. The number of seeds produced annually on inland sites ranges from 12,800 per acre (31,600/ha) to 23,500 per acre (58,100/ha) [71]. The winged seeds are of medium weight compared to other conifers and are wind-dispersed a few hundred feet from the parent [14,183]. Over 4 years (1974-1977), grand fir seed rain in central Oregon ranged from 810 to 60,718 seeds per acre (2025-151,795/ha) per year; sound seed ranged from 4.5 to 33.3% [158]. Seeds stratify over winter and are not viable beyond the 1st spring [71,123,148,183]. Germination is extremely variable but is seldom over 50% [14,71,54]. Li and others [126] found that in collections from coastal British Columbia, light increased germination rates in unstratified seed (light/dark germination= 89/80%) but had no significant effect on germination rates of stratified seed (92/93%, p=0.05) [71].

Seedling establishment: Despite the perception of grand fir as a primarily late-successional species, it shows good establishment on recently disturbed sites [10,78], and mineral soil is the most favorable seedbed [78,158]. Grand fir also establishes in light to moderate understory shade and in small openings in mature forests [10]. Uneven-aged grand fir establishment may occur over an "extended period of years" [87].

Over 30% of grand fir seedlings die during the 1st year, and an additional 10% die their 2nd year. Biotic agents and drought usually cause early losses. Initial seedling root penetration is deep on sites exposed to full sunlight so that seedlings are relatively resistant to drought. However, on shaded sites root penetration is slow, and drought is the major cause of seedling mortality [71,45]. East of the Cascade crest, water deficits are seldom critical past the seedling stage [103,198].

Grand fir has shown good establishment after silvicultural treatments. After shelterwood cutting in grand fir-Shasta red fir in central Oregon, seedling establishment of both firs was best on mineral soil (created by bulldozing). Seedling density decreased as litter and slash depth increased [158]. In central Idaho, grand fir showed better seedling establishment than 5 associated conifers on logged sites, establishing on clearcuts or shelterwood cuts within an average of 7 years (range=0-30 yrs). It was less successful than most conifer associates on broadcast burned sites, but still showed 33% frequency on lightly scarified burns and 23% frequency on heavily scarified burns [78]. A western redcedar-western hemlock/pachistima habitat type on the Deception Creek Experimental Forest of northern Idaho was horse-logged (shelterwood cut or clearcut followed by broadcast burning). Four years after treatments, grand fir showed moderately good seedling establishment compared to 6 other conifer species; only western white pine and western hemlock established in greater densities. Density of grand fir averaged 1.4 seedlings/yd^2 (1.8/m^2) on the shelterwood site and 0.1 seedling/yd^2 (0.2/m^2) on the clearcut and broadcast burned site. Grand fir continued to establish during the 20-year study period. Twenty years after treatment, grand fir density was still moderate compared to other conifers, at 12.1 stems/yd^2 (15.1/m^2) on the shelterwood and 2.5 stems/yd^2 (3.1/m^2) on the clearcut [23].

Growth: Grand fir is the fastest growing of all North American firs. It may reach 140 feet (43 m) in 50 years on Coastal Range and interior northern California sites [156]. On the eastern slope of the Cascade Range, Washington, grand fir grew more rapidly in the absence of Douglas-fir but was not affected by presence or absence of lodgepole pine [39].

Vegetative reproduction: Grand fir reproduces solely from seed and does not sprout from the root crown [71,155]. It may produce epicormic branches on the lower bole if light and space become available. Epicormic sprouting may contribute considerable volume to a disturbed stand [14].

SITE CHARACTERISTICS:

Climate and moisture regime: Grand fir tends to dominate moderately moist habitats. In the northern Rocky Mountains, grand fir habitat types indicate areas where the climate is moderated by the Pacific maritime influence [43,145,171]. Generally, drier sites are occupied by Douglas-fir while western redcedar and western hemlock dominate wetter habitats [10,38,131]. Inland, grand fir is most abundant on sites averaging 25 inches (635 mm) or more annual precipitation that are either too dry for, or beyond the range of, western hemlock and western redcedar [14]. Habeck [84] found that in the Selway-Bitterroot Wilderness of northern Idaho and western Montana, grand fir forests were most extensive on mid-elevation (3,500-4,00 feet), mesic slopes. They fingered into wetter, western redcedar types and were scarce on drier types. Grand fir is a relatively minor stand component in wet, dense coastal forests [187]. In southern British Columbia, it is most common on moist soils and is infrequent on dry or wet soils [117]. Although it is the most drought-tolerant of the Pacific Northwest firs, moisture is limiting in grand fir's southernmost distribution. Grand fir occurs only on moist slopes in northeastern California [174]. West of the Cascade Range in Oregon and California, it occurs mainly on moist valley bottoms [14].

Grand fir is tolerant of fluctuating water tables and floods [117].

Soils: Soil parent materials in which grand fir grows include sandstone, pumice, weathered lava or granite, and gneiss [71,31]. Grand fir is not generally restricted by soil type but does best on streamside alluvium and deep, nutrient-rich valley bottoms [71,117,155,174]. If there is adequate moisture, grand fir in central and eastern Oregon grows on pumice and other shallow, exposed soils [71]. On the Mendocino Coast of California grand fir occurs on soils of pH 5 [107].

Elevation: Grand fir occurs at elevations up to 6,000 feet (1,830 m) in the Cascade Range and northern

Rocky Mountains [14,71]. West of the Cascade Range, it is usually restricted to low-elevation valleys [14]. Elevations are listed below by region.

	Minimum feet (m)	Maximum feet (m)
western British Columbia	sea level	1000 (305) [14]
California	sea level	5000 (1525) [14,71,102,174]
Idaho	2000 (610)	6000 (1830) [122,19]
western Montana	4300 (1290)	4700 (1410) [11]
Oregon Cascades	----	6025 (1825) [14,71,174]
western Oregon	sea level	3000 (915) [14]
Washington Cascades	----	4000 (1220) [14,71,174]
western Washington	590 (180)	1000 (305) [14,174]

SUCCESSIONAL STATUS:

Grand fir occurs in the overstory of both seral and late-successional forests [9,71,91,47,52,83,87]. It is climax throughout the grand fir series and is a major seral species in some western redcedar, western hemlock, subalpine fir, and Pacific silver fir habitat types [91]. It exhibits moderate growth in the open, yet is shade-tolerant enough to establish and grow beneath an open forest canopy [9,60,130,145,183]. Grand fir is not as shade-tolerant as western redcedar, hemlocks, or other firs and does not establish beneath a closed canopy [71,156,148,155,187,183]. Succession to a grand fir overstory is usually slower on shrubfields than on sites where grand fir developed beneath a forest canopy [10,49,157]. In grand fir habitats on Clearwater River drainages in northern Idaho, succession to a woody overstory was retarded by bracken fern (*Pteridium aquilinum*) or western coneflower (*Rudbeckia occidentalis*) invasion, and by northern pocket gopher browsing young grand fir and other conifer regeneration [59].

Grand fir does not require disturbance to establish and persist on most sites [15,188]; however, where western hemlock or western redcedar is the climax dominant, fire or other periodic disturbance is needed to maintain grand fir [14]. Grand fir may colonize a site soon after fire or other stand-replacing disturbance. Grand fir advance regeneration and seedling coverage were highest among 5 conifers following a severe Douglas-fir tussock moth outbreak that killed most of the grand fir-Douglas-fir overstory on the Wenaha-Tucannon Wilderness, Oregon. Although ponderosa pine seedlings showed faster growth rates than grand fir seedlings, the authors predicted that in the absence of fire, grand fir would continue to dominate the site despite repeated tussock moth outbreaks [192].

In the Swan Valley of western Montana, a grand fir understory usually developed in late succession beneath Douglas-fir that replaced early-succession lodgepole pine and western larch. Grand fir seedling establishment on early seral sites occurred mainly where lodgepole pine and western larch seed sources were lacking, such as the center of large, stand-replacement burns [9]. Descriptions of seral communities that occur in grand fir habitat types in Montana's Swan Valley and in central Idaho are available [9,43,171,172].

Dale and others [47] developed a model of long-term succession (500+ years) in western Washington and Oregon. The model predicts that in the absence of disturbance, grand fir is an early mid-seral species that is eventually replaced by Pacific silver fir, western hemlock, and mountain hemlock (*Tsuga mertensiana*). The model also predicts successional pathways after disturbance events including fire, windstorm, insect outbreak, and clearcutting.

SEASONAL DEVELOPMENT:

Time of grand fir budding varies over several months depending on early spring temperatures. Generally, budding occurs from late March to mid-May at low elevations and in June at higher elevations [71,75]. Shoot elongation follows bud burst; cones generally open for pollination during shoot elongation [54,75]. Cones ripen from August to September of the same year and begin to disintegrate and dispense seed about a month later [71,75].

Grand fir phenology in several locations is given below [179]:

Location	Bud break	Pollination	Cones ripen	Seeds disperse
BC	mid-March	April	August	---- (no data)
northern ID	mid-June	----	August	early Sept.
western OR and WA	mid-April to mid-May	----	----	mid-Sept.
Linn Co., OR	mid-June	----	----	----
Mendocino Co., CA	early April	----	----	----

Phenological observations of grand fir made over an 8-year period in northern Idaho and western Montana are summarized below [157]:

	Earliest date	Average date	Latest date
Shoots start	April 19	May 18	June 25
Buds burst	April 5	May 25	June 11
Pollen starts	May 1	June 4	July 2
Pollen ends	May 20	June 20	July 14
Shoot growth ends	June 9	August 3	August 31
Winter buds formed	June 16	August 14	October 11
Cones full size	July 7	August 5	August 26
Cones open	August 30	September 9	October 11

FIRE ECOLOGY

SPECIES: Abies grandis

- FIRE ECOLOGY OR ADAPTATIONS
- POSTFIRE REGENERATION STRATEGY

FIRE ECOLOGY OR ADAPTATIONS:

Adaptations to fire: Grand fir is moderately resistant to frequent surface fire. It has thin bark and is easily killed when young, but the bark is thick enough at maturity (about 2 inches (5 cm)) to provide resistance to low- and moderate-severity fires [3,169,44,50,69,89,92]. Compared to other Pacific Coast conifers, it is less fire resistant than coastal Douglas-fir but more so than western hemlock and Pacific silver fir [70]. Inland, it is less fire resistant than western larch, Pacific ponderosa pine, and Rocky

Mountain Douglas-fir; about the same as white fir; and more fire resistant than western white pine, subalpine fir, Engelmann spruce (*Picea engelmannii*), and Rocky Mountain lodgepole pine [148,70]. Fire-scarred grand fir are susceptible to heart rot [7,9,14,108,62].

Grand fir does not survive crowning or severe fire. Its low, dense branching habit, flammable foliage, and tendency to develop dense stands with heavy lichen growth increase the likelihood of torching and mortality from crown fire [44,50,69,169].

Fire strongly influences grand fir's ecological niche and successional role [91,108]. In coastal British Columbia grand fir occurs in areas of relatively low summer rainfall and high summer temperatures, suggesting that its range may be restricted to sites with higher fire frequencies compared to moister surrounding forests with longer fire return intervals [155]. On many Pacific Northwest sites, however, grand fir only dominates sites where fire is excluded. Fire history studies show that Oregon white oak, Port-Orford-cedar (*Chamaecyparis lawsoniana*), Pacific ponderosa pine, western larch, and/or coastal Douglas-fir were maintained as site dominants by frequent surface fires that eliminated young grand fir [90,91,81]. After cessation of Native American burning in the Willamette Valley of Oregon (around 1850), grand fir has successionally replaced Oregon white oak and coastal Douglas-fir on most sites. Coastal Douglas-fir retains dominance only on the driest sites in the valley [42]. Although grand fir is not usually seral on sites with frequent fires, it may be either climax or seral on sites that experience infrequent crown fires [91].

Fire regimes: Fires in grand fir types were historically of mixed severity, with fire behaviors ranging from frequent low-severity, nonlethal surface fire to infrequent, stand-replacing crown fire [9,3,5,18,139,12,166,19]. The grand fir series can roughly be divided into warm/dry types and warm/moist types. In warm/dry types, the historical fire regime was frequent (5-50 year), low-severity fire that favored Pacific ponderosa pine and western larch [11,34,170,190]. For example, a mean fire return interval of 47 years is reported for the Blue Mountains [190], with a range of 33 to 100 years [194]. Historically, fire severity in grand fir types of the Blue Mountains was often moderate, with a wider range of fire severities than Douglas-fir types [3]. Dry grand fir/graminoid types with understories of elk sedge or pinegrass typically experienced frequent surface fires (10- to 25-year intervals) [6,128,191].

Fire regimes in northern Idaho and western Montana were historically similar to those in the Blue Mountains, but fire return intervals showed a wider range (3-200 years) [9,11]. On a dry site in the Bitterroot National Forest of western Montana, Arno [162,171] reported a mean fire return interval of 17 years between 1735 and 1900, with a range of 3 to 32 years. He attributed the short fire return interval to the relative scarcity of the grand fir series there, so that grand fir had "fire frequencies much like those in surrounding major series" such as Rocky Mountain Douglas-fir [16,12].

Mixed-severity fires with longer return intervals (25-100 years) were more common on cooler, moderately moist grand fir types with Rocky Mountain maple, Pacific yew, oak fern (*Gymnocarpium dryoptera*), or sword fern (*Polystichum munitum*) understories. Fire regimes shifted to moderate severity on these wetter sites, and stand-replacement fires were more common [3,6,34,12,166,19]. Fire-scarred, mature grand fir trees in northern Idaho have withstood moderate-severity surface fires once or twice a century [18]. Camp [34] reported that fire history was complex on warm/moist forests of the eastern slope of the Cascade Range in Washington, with evidence of both frequent, low-severity fires and infrequent severe, stand-replacing fires. Sites experiencing severe fire often escaped fire through 2 to 3 surface fire cycles that occurred in surrounding forest. These long-unburned sites developed into multi-layered grand fir forest that functioned as old-growth fire refugia until the next severe fire cycle.

Presettlement sites of fire refugia occurred most often on north-facing aspects, benches, valley bottoms, and stream confluences and headwalls [34,35].

Long-interval (> 100 years), severe fires were most common on wet grand fir habitat types [12,166,19]. Moist types are highly productive and have large fuel loads [94]. Barrett [18] found that fires in grand fir of the Clearwater National Forest in northern Idaho were usually large and exhibited behavior of (1) moderate to severe surface fires that killed the grand fir but left a few fire-resistant seral conifers, and (2) running crown fires (with individual runs of several hundred acres) that killed entire stands. Even given this extreme fire behavior, there was also evidence of low-severity surface fires, particularly on north slopes, that scarred but did not kill grand fir [18]. Barrett and Arno [19] found that patchy, stand-replacement fires with a mean return interval of 119 years typified fire regimes in Rocky Mountain Douglas-fir/grand fir habitats of the Selway-Bitterroot Wilderness in northern Idaho. A minority of stands experienced mixed-severity fire of nonuniform spread. Long-interval, stand-replacing fire also occurred historically in the relatively moist Swan Valley of western Montana. The Swan Valley also shows evidence of a mixed fire regime, with a mosaic of stands of varying age and composition [9]. Fire return intervals in the Swan Valley ranged from 20 to 300+ years, with a mean of 150 years [9,10].

Fire regimes for plant communities and ecosystems where grand fir is a common associate are summarized below. Find further fire regime information for the plant communities in which this species may occur by entering the species name in the FEIS home page under "Find Fire Regimes".

Community or Ecosystem	Dominant Species	Fire Return Interval Range in Years
Pacific ponderosa pine*	*Pinus ponderosa* var. *ponderosa*	1-47 [25]
Rocky Mountain lodgepole pine*	*P. contorta* var. *latifolia*	25-300+ [12,151]
Rocky Mountain Douglas-fir*	*Pseudotsuga menziesii* var. *glauca*	25-100 [25]
coastal Douglas-fir*	*Pseudotsuga menziesii* var. *menziesii*	95-242 [138,149]
quaking aspen (west of the Great Plains)	*Populus tremuloides*	7-100 [132,82]
redwood	*Sequoia sempervirens*	7-25 [66,178]

*Fire-return interval varies widely; trends in variation are noted in the Species Review.

POSTFIRE REGENERATION STRATEGY [177]:

Tree without adventitious bud/root crown
Initial off-site colonizer (off-site, initial community)
Crown residual colonizer (on-site, initial community)
Secondary colonizer - off-site seed

FIRE EFFECTS

SPECIES: Abies grandis

IMMEDIATE FIRE EFFECT ON PLANT:

Young grand fir have thin bark and are easily killed by fire [109,112]. Trees under 4 inches (10.2 cm) diameter at ground level are most susceptible to direct fire mortality [89,92]. The bark thickens as trees age, and mature trees are moderately resistant to fire [12,34]. Ground fires burning into the duff injure shallow roots and may kill even mature trees [44,67,71,108,164].

Baker [71] found that grand fir seedlings in the laboratory were killed by exposing the stems to temperatures of 121 degrees Fahrenheit (49°C) for 10 minutes.

DISCUSSION AND QUALIFICATION OF FIRE EFFECT:

Because grand fir wood does not contain decay-inhibiting properties nor exude pitch over wounds, trees that survive fire are susceptible to the entry of decay fungi through fire scars and stimulation of dormant decay by fire injury. The problem is more serious east of the Cascade Range crest because of the ubiquitousness of Indian paint fungus in the eastern portion of grand fir's range. [7,8,9,14,16,108,62].

PLANT RESPONSE TO FIRE:
Grand fir regeneration is common after fire [9,155]. Seedlings establish on burns mostly from off-site seed sources [8,109,182]. Mature grand fir that survive a fire provide an on-site seed source [8]. Fire provides a favorable seedbed. When different substrates were compared, grand fir germination was best on ash or mineral soil [69,162]; however, seedling mortality may be higher on burned soils due to higher surface temperatures on blackened compared to unburned soils [159]. Seedlings often establish in the 1st few postfire years. For example, following a severe wildfire in a mature grand fir/queencup beadlily association in the Blue Mountains of Oregon, grand fir seedlings were 1st noted in study plots at postfire year 5 [109]. Following the Sundance Fire in northern Idaho, grand fir seedlings were 1st noted in postfire years 4 to 9, with time of 1st emergence varying among study plots. [176]. Because grand fir seedlings are not as drought tolerant as many conifer associates, grand fir establishment is sometimes slow or delayed by drought, but grand fir is usually established as component of seral vegetation by 20 to 30 years after fire [133,196]. Grand fir regeneration is also common after fire thins a dense overstory [9]. As a shade-tolerant tree, grand fir continues to establish until canopy closure in late succession [112].

Low-severity fire may have little effect on grand fir. A "light" fire in an early-seral grand fir/twinflower association the Oregon Blue Mountains killed the pole-sized overstory conifers (grand fir, Rocky Mountain Douglas-fir, and Rocky Mountain lodgepole pine), but their relative coverage remained similar to prefire levels during early postfire seedling establishment. Prefire coverage of grand fir was 5% compared to 3% coverage at postfire year 5 [109].

FEIS provides these Fire Studies on plant communities in which grand fir is an important component of the vegetation:

- Research Project Summary: Prescribed and wildfire in clearcut mixed-conifer forests of Miller Creek and Newman Ridge, Montana
- Research Paper: A comparison of dry and moist fuel underburning in ponderosa pine shelterwood units in Idaho

DISCUSSION AND QUALIFICATION OF PLANT RESPONSE:

In northeastern Oregon, 3 wildfire sites were selected to study fire's effects on late-seral grand fir/big huckleberry associations. Two sites were severely burned, and 1 site was lightly underburned. The severe fires killed all overstory and understory grand fir. The low-severity fire was continuous with fire scorching only the basal portion of the large-diameter (30-40 inch (76-102 cm)) trees. The low-severity fire reduced overstory grand fir coverage from 55 to 40%, and the understory was reduced from 10 to 5%. A thicket of grand fir saplings was reduced by 30% [109].

Fire may aid grand fir regeneration on most sites, but grand fir may regenerate poorly after fire on south-facing slopes or on dry sites [58,98]. In a grand fir/pachistima habitat in the Coeur d'Alene River drainage of northern Idaho, grand fir established readily on unburned sites following clearcutting, but required shade for regeneration on clearcut and burned sites [195].

A prescribed stand-replacment fire in a mixed lodgepole pine-subalpine fir-grand fir forest in eastern Washington. The fire was set to create summer elk range habitat. Image used with permission of James N. Long, Utah State University, Bugwood.org.

FIRE MANAGEMENT CONSIDERATIONS:

Historically, low-severity surface fires and patchy, mixed-severity fires killed young grand fir and Douglas-fir in the understory while favoring early-seral, fire-tolerant tree species including Oregon white oak, ponderosa pine, Douglas-fir, and western larch [81,111,190,191]. Once open, park-like stands are being invaded by grand fir, other firs, and Douglas-fir, resulting in poor regeneration of early-successional trees [81,15,34,130,190,191]. Fuel loads have increased and produced very fire-prone communities with high probabilities of crown fires [91,92]. Fire exclusion has altered forest structure and affected understory vegetation [111]. Stands have developed understories or multiple canopy layers of grand fir and other shade-tolerant species [34]. These understories may be extremely dense, often thousands of stems per acre. Without fire, understory grand fir usually develop into thickets of stressed trees [15].

Underburning in grand fir stands reduces fuels and permits regeneration of pines and other fire-tolerant trees [136]. Several factors are considered in predicting and modelling mortality of grand fir and other conifers [154]. Underburning grand fir on steep ground generally results in high mortality [22]. Mortality is also dependent on bark thickness, stand structure, and duration of fire. Peterson and Ryan [144] present a model for predicting mortality of grand fir, subalpine fir, and Douglas-fir in the northern Rocky Mountains based on tree morphology, stand structure, and fire characteristics.

Fuels and fire behavior: Grand fir forests are usually highly productive, which leads to rapid fuel accumulation [85]. Mid-slope forests such as those occupied by grand fir are more prone to severe, stand-replacing fire than forests at lower or higher elevations [12,34]. Habeck [162] found that fuel loads in old-growth grand fir (> 250 years of age) in the Selway-Bitterroot Wilderness often exceeded 41 tons per acre (100 t/ha), with litter and duff layers averaging 5 inches (12 cm). Such highly productive sites are subject to reburn. Barrett [18] defines a reburn as a fire that burns in heavy downed woody fuel resulting from tree mortality in a previous fire, occurring when tree regeneration is in the seedling or sapling stage. Barrett [18] found that on the Clearwater National Forest, the driest aspects were most likely to reburn, but potential for reburn was also present on productive north slopes.

Average heat release of live grand fir has been summarized as follows [114]:

Wood		Bark		Twigs		Foliage	
BTU/lb	(Mj/kg)	BTU/lb	(Mj/kg)	BTU/lb	(Mj/kg)	BTU/lb	(Mj/kg)
8,300	(19.31)	9,641	(22.43)	8,894	(20.69)	9,497	(22.09)

In a literature summary, Minore [148] reports that fire spread in fresh grand fir slash is intermediate compared to slash of 7 associated conifers. Fire spread in 1-year-old grand fir slash is slower than fire spread in 1-year-old slash of all associated conifers except western larch, in which fire spread is similar. Photo guides have been prepared for appraising slash fuels in grand fir forests of northern Idaho, and for downed woody fuels in grand fir, western larch, and Douglas-fir forests of Montana [67,119].

Fuel models: Brown [24] and Moeur [135] present equations for predicting crown width and foliage biomass of grand fir and associated conifers.

Keane and others [112] predict that decomposition rates of litter in grand fir-dominated forests are an order of magnitude less than in ponderosa pine or Douglas-fir forests.

Fire behavior models: Agee [4] provides models for predicting stand conditions that initiate crown fire in grand fir and other western forest types based on the critical surface fire intensity needed to initiate crowning (equation 1), and for identifying conditions that allow crown fire to spread (equation 2):

$I_o = (Czh)^{3/2}$ (equation 1)
where
I_o = critical surface intensity
C = 0.010 (constant)
z = crown base height
h = heat of ignition (largely a function of crown moisture content), and

E = Rdh (equation 2)
where
E = net horizontal heat flux, kW/m^2
R = rate of spread, m/sec
d = bulk density of crown, kg/m^3
h = heat of ignition, kJ/kg

Restoration: The general objective of restorative management is to develop open stands of seral conifers resembling stands maintained by historic fire regimes. Restoring presettlement stand conditions and fire regimes to grand fir habitats also reduces stand susceptibility to outbreaks of insect and fungi [37]. Because of dense understories of grand fir and other shade tolerant conifers, it is usually necessary to begin restoration with a "low thinning" treatment that removes excess understory and weak understory trees. Low-severity prescribed fire is then conducted to reduce fuel loadings, kill understory conifers, and promote herbaceous and shrub species in the understory. Once thinning and burning are accomplished, the stand can be maintained by periodic underburning alone, at 15- to 30-year intervals [15]. A selection cutting that retains many of the dominant overstory trees also helps maintain open-stand conditions when tree harvesting is an objective [15,38].

Range productivity: Some sites are less useful for livestock grazing as a result of fire exclusion [111]. Hall [90] reported that in the Blue Mountains of Oregon, forests that have been maintained as ponderosa pine/pinegrass by periodic underburning (< 50% crown cover) produce 500 to 600 pounds of pinegrass per acre (562-675 kg/ha). In forests where fire has been excluded and grand fir and Douglas-fir have established a subcanopy (> 80% cover), pinegrass production drops to 50 to 100 pounds per acre (56-112 kg/ha)[90].

Wildlife habitat: Historically, fire refugia sites in the grand fir and Douglas-fir-grand fir series were important habitat for late-successional animals such as northern spotted owl and American martin [34,35,36]. Camp and others [35] provide a model for predicting occurrence of fire refugia based on topographic and physiographic variables.

Abies grandis: References

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